Responses to Dr. Mark E. Grismer's memorandum entitled, *Feasibility of Using "Reduced-Runoff" Surface Irrigation for Hay Crops Grown on Heavy Clay Soils in the Imperial Irrigation District,* dated May 27, 2003.

Natural Resources Consulting Engineers, Inc.
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Understanding of the Irrigation-Drainage-Soil Salinity Process in Heavy Cracking Soils

Dr. Grismer provides a discussion concerning the soil salinity, groundwater salinity, and irrigation of cracking soils, stating that NRCE's 2002 report contains an incomplete understanding. He states that on an annual basis, "more than 90 percent of the tile drainage flows are from shallow groundwater rather than percolation" and that "tile drainage systems may be of little practical benefit to growers." NRCE disagrees strongly with these statements. Tile drains are only effective when a water table is present at or above the tile drains. Irrigation deep percolation enters the soil vertically and most water that flows to the tile drains enters by both upward and horizontal flow. It is common knowledge that that very little water in the tile drains results from deep percolation of recently applied irrigation water. Relevant evidence demonstrates that it is groundwater, fed almost exclusively by the deep percolation from irrigation, that flows to the tile drains. Most flow paths of irrigation water to drains are long in duration and some of the water may take decades to reach the drains, so some of the drain water may be historic groundwater or irrigation water that has a different chemistry resulting from movement through soil below the root zone over a period of time. However, this does not mean that the drains are of little practical benefit to growers. The reality is that given the physical circumstances of farming in the Imperial Valley, with heavy soils, highly saline water, and other relevant factors, underground (tile) drains are essential to maintain productivity of the soil and to support sustained agricultural production

Dr. Grismer's discussion on irrigation, salinity, and drainage is confusing and has little relevance to reduced-runoff irrigation. For example, he states that there is "Little upward movement of groundwater"; implying that there is at least some upward movement of the groundwater. He also states that there is "Limited downward movement of irrigation water"; implying that there is at least some downward movement of irrigation water. NRCE disagrees strongly with both of these statements. Both statements understate the movement of ground water upward toward the drains, and the movement of deep percolation downward either directly into the drains or to the ground water table and then eventually into the drains. If all the water that moves up and down within the soil profile is used by crops or evaporates without flowing to drains, then the soil's salinity would steadily increase until crops could not be grown. Since the Imperial Valley remains a very viable farming area, with largely extremely productive soils, common sense dictates that soil salinity is being controlled effectively and that is largely due to the underground drainage system.

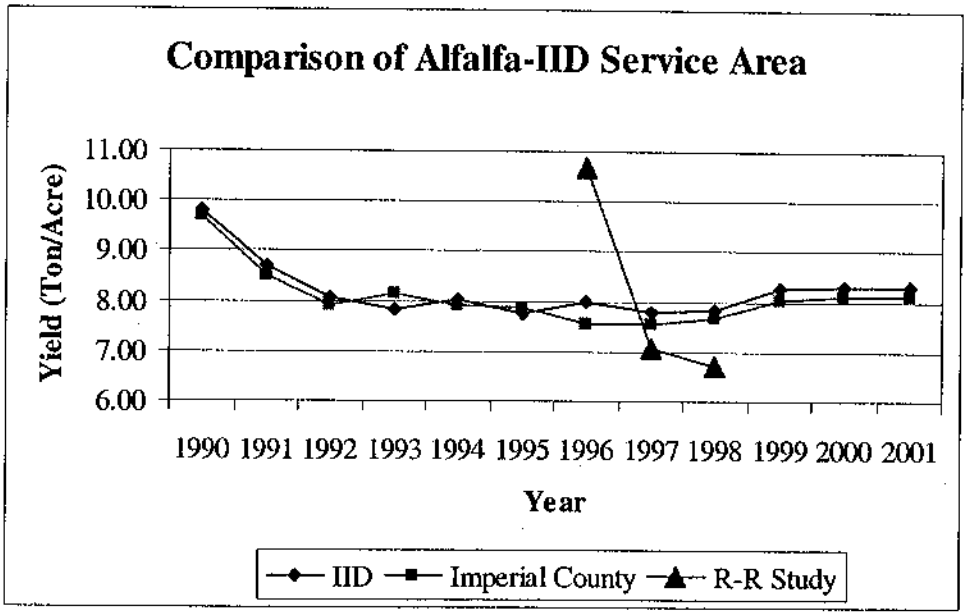
The facts are that salts are removed from the root zone through vertical drainage, water table levels are controlled by tile drains and open drains, and tile drain flows are influenced by irrigation (flowing at a higher rate during and for a few days after the irrigation). Without tile drains most of the valley would have high water tables and salinity problems that would severely limit the production of crops. It is absurd to think that 34,000 miles of tile drains have been installed with little practical benefit to growers.

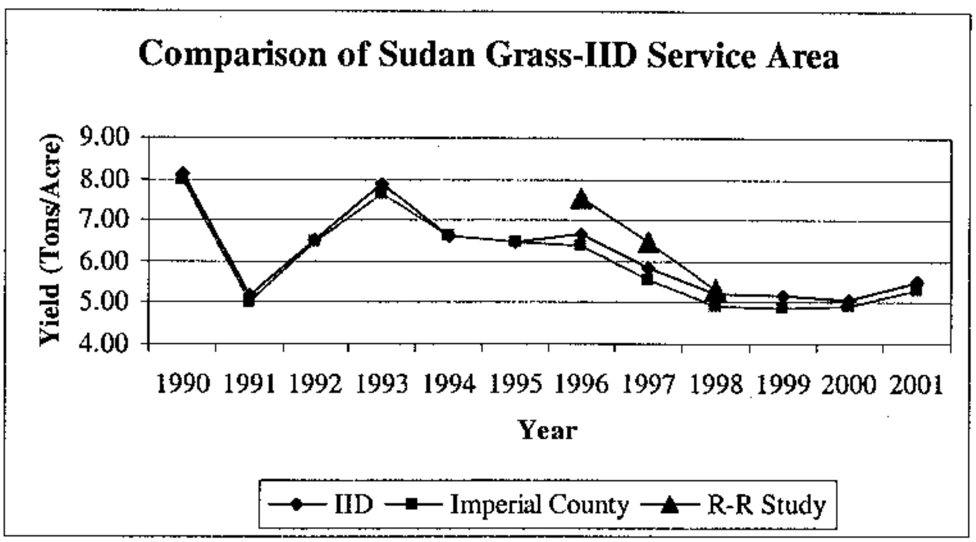
Application of Reduced-Runoff Surface Irrigation

Dr. Grismer stated "The R-R surface irrigation method has been applied successfully to border-check irrigation of alfalfa and sudangrass hay grown on heavy clay soil classifications that comprise about 41% of the Imperial Valley soils" (Grismer, 2003). He also stated "...the R-R irrigation method is potentially applicable to all border-irrigated heavy cracking soils within Imperial Irrigation District (IID) which comprise 62 to 69% of the Imperial Valley soils. Moreover, the method can be readily applied to border-check irrigation of crops grown on mildly sloping fields that are found across more than half of the IID area" (Grismer, 2003). Dr. Grismer's studies were conducted at the University of California Desert Research & Extension Center on small plots with unique soil, groundwater, and management conditions. Conditions throughout the valley are different and need to be evaluated more realistically. Importantly, the results of the Grismer research show an annual decrease in yields for both alfalfa and Sudan grass hay. The results also show an overall increase in soil salinity during the alfalfa growing period.

The long-term effects of reduced runoff irrigation is not known and the level of more intensive management required is difficult to maintain in commercial agriculture due to the constraints of labor and IID's delivery system operations. For example, there is significant impact on yield resulting from under irrigation or no irrigation at the end of the field. The application of the reduced-runoff irrigation method to drastically limit tailwater throughout IID has not been effectively and scientifically determined to be practical or feasible. For the test plots evaluated, an annual decrease in yield was observed for both alfalfa and the Sudan grass. The alfalfa yield decreased from 23.96

Mg/ha in 1996 to 15.08 Mg/ha in 1998 and Sudan grass yield decreased from 16.9 Mg/ha in 1996 to 11.9 Mg/ha in 1998. Alfalfa yields were greater than the county average only for the first year of the reduced-runoff irrigation experiment (see figures below). Importantly, one would expect a higher yield on research plots than county averages due to the high level of management.





The wide-spread adoption of this irrigation management method could result in salt accumulation in the soils and significant economic hardships for growers. The gross losses to alfalfa growers if implemented throughout IID could be $12 million per year (120,000 acres (total alfalfa acreage is about 170,000) times 1 ton per acre (yield reduction) times $100 per ton). The average of one ton per acre reduction in alfalfa yield is based on the nearly four tons per acre decrease during a three year period that the reduced-runoff irrigation method was researched. An exact value is not appropriate to extend to all the acreage based on limited research. The yield is expected to decrease into the fourth year if the research is continued.

As Dr. Grismer states, the reduced-runoff irrigation method relies on '*estimating or predicting*' the irrigation set time for the applied water to completely spread across and down the border (Grismer report at page 3). NRCE's observation is that irrigators estimate and predict irrigation set times to limit tailwater to the amount that is needed to provide an adequate irrigation, based on available information and existing constraints. A single irrigator may manage irrigations on one or more fields simultaneously, while in contrast there are likely multiple researchers and staff conducting the reduced-runoff irrigation experiments on a few borders. Based on irrigation evaluations and field observations in IID, irrigators nearly always shut off the water prior to the water reaching the end of the border.

As previously stated, the reduced-runoff irrigation method relies on '*estimating or predicting*' the irrigation set time. However, the advance rate of the water down a border is a function of many variables; two variables which are usually different for each irrigation are 1) the soil moisture (which influences the soil cracking extent) and 2) the density and roughness of the vegetation (which influences depth of flow, water stored on the surface of the field, and velocity of flow). The impact of these variables on advance rates are not known until after the irrigation has begun and the delivery order has been placed. There are no practical or reasonable methods to assess all the variables that impact the optimal irrigation duration with the accuracy required to limit tailwater as was done in the reduced-runoff irrigation experiments. Experience obtained from small plots where there is intensive management with no realistic limitation on costs is not relevant to the realistic circumstances of sustained farming operations on about 475,000 acres of land.

Although the reduced-runoff irrigation method results in minimal, if any, tailwater, it has not been demonstrated that there will be no adverse salinity effects (as asserted by Dr. Grismer) when applied to large-scale commercial alfalfa and Sudan grass production on heavy soils in the Imperial Valley. Based on field observations and assessments, most irrigators cut off water when it advances to a determined location ahead of the field end to minimize runoff (tailwater), but it is not necessarily targeted to 2 percent of the inflow as advocated by Dr. Grismer on page 7. Stated simply, the additional water conservation opportunities from this technique are not known, and the yield reduction consequences of this approach are also not effectively demonstrated.

The use of regulating reservoirs

As stated by Dr. Grismer, the reduced-runoff irrigation method relies on the ability to significantly increase control of water flows from the head ditch and control of the cutoff times. One of his suggestions is that an on-site small regulating reservoir should be used in order to accomplish these goals. However, it is estimated that the annual operating cost to conserve water with a field regulating reservoir is $84 per acre-foot of water conserved, approximately five times the current per acre foot cost of water deliveries from IID.

Under current operating conditions, on-farm water supply delivered from the lateral for an irrigation is relatively constant and for a pre-determined duration. Water savings could be realized by having the increased capability to cutoff water from the field prior to the end of the irrigation delivery and also by being able to finish an irrigation after the scheduled delivery. A small, 6 acre-foot reservoir (for 140 acres) located at the head of the field to provide flow control capability would be useful in meeting these goals. The size of the reservoir is based on holding up to 12 percent of the ordered irrigation delivery (50 acre-foot order = approximately 4.5 inch irrigation order on 140 acres). Without on-farm regulating reservoirs, cutting off irrigation supplies prematurely and returning the scheduled irrigation delivery to the laterals may result in spills and fluctuating field deliveries downstream.

Field-by-field regulating reservoirs could be used to cutback irrigation by initially being partially filled, followed by greater than average withdrawals during the advance phase of irrigation, followed by lower than average flows during the cutback phase. The reservoir's capacity would essentially provide the irrigator with a controllable headgate to more effectively meet irrigation needs. In general, the increased water control capabilities provide for more efficient irrigations.

It is most important, however, to focus realistically on the limitations and consequences of having the luxury of a regulating reservoir at every field. The creation of on-farm regulating reservoirs would require some land to be taken out of production and they would require increased management and labor. In addition, there are seepage and evaporation losses associated with the reservoirs. Also, nearly all on-farm regulating reservoirs would require a pump to put unused water back into the head ditch. The bottom line is that all of these consequences come with costs, and those costs translate into increased costs of production on a per acre basis. Stated differently, it is irresponsible to suggest improvements such as regulating reservoirs without being realistic about the costs associated with such improvements.

Construction Costs for On-farm Regulating Reservoir					
	Unit	**Quant.**	**$/unit**	**Total**	**Annual**
Reservoir (6 acre-feet capacity)	L.S.	1	$9,750.00	$9,750	$1,139
Headgates and Water Control	L.S.	1	$600.00	$600	$70
Pump (diesel)	L.S.	1	$4,500.00	$4,500	$526
Total				**$14,850**	**$1,735**

Notes:
L.S. = lump sum
Annual costs based on 8 percent annual interest rates for 15 years.
Reservoir cost is based on 6,500 cubic yards of excavation and compaction at $1.50 per cubic yard.
Pump is a powered by a diesel engine, due to 3-phase power not being available throughout IID (10 cfs at 10 feet of head, about 16 BHP - 20 HP engine).

Annual Costs for On-farm Regulating Reservoir				
	Unit	**Quant.**	**Rate**	**Total**
Reservoir Construction	L.S.	1	$1,139	$1,139
Headgates and Water Control	L.S.	1	$70	$70
Pump (diesel)	L.S.	1	$526	$526
Pump Operation (energy)	gallons	96	$1.00	$96
Pump O&M	L.S.	1	$50.00	$50
Reservoir O&M	L.S.	1	$100.00	$100
Labor	hrs	64	$9.25	$592
Net Reciepts (Land lost to production)	acres	1.5	$250.00	$375
Total				**$2,948**
Estimated tailwater savings	ac-ft/ac	0.25		
Acreage	ac	140		
Total Annual Water Savings	**ac-ft**	**35**		
Costs per acre-foot	**$/ac-ft**	**$84**		

Notes:
Energy costs based on 5 acre-feet per irrigation at 10 cfs takes 6 hours, at one gallon per hour for 16 irrigations.
O&M for reservoir is for weed control and periodic dredging.
16 irrigations x 4 hours (UC Cooperative Extension Rate).
Net loss revenue is based on typical revenue from one acre of production.

Conclusion

It is extremely important to understand that the Grismer conclusions regarding the reduced-runoff irrigation method are based on small field studies carried out under highly controlled circumstances. Accordingly, it is not accurate to conclude that the Grismer results could be achieved in the context of large-scale farming under the physical circumstances found in the Imperial Valley. Similarly, the Grismer report does not accurately reflect what degree of reduced productivity might result from the reduced-runoff irrigation method. Finally, Grismer's suggestion of the use of regulating reservoirs, actually essential to make his approach work in the real world, does not accurately reflect the multitude of costs that would have to be incurred to implement such reservoirs.

REFERENCES

Grismer, M.E. (2003). "Feasibility of Using 'Reduced-Runoff' Surface Irrigation for Hay Crops Grown on Heavy Clay Soils in the Imperial Irrigation District." Memorandum dated May 27, 2003.

Attachment 1

Grismer, M.E. (2003). "Feasibility of Using 'Reduced-Runoff' Surface Irrigation for Hay Crops Grown on Heavy Clay Soils in the Imperial Irrigation District." Memorandum dated May 27, 2003.

Mark E. Grismer PhD

Vadose Zone Hydrologist

MEMO

Date: May 27, 2003

To: Kirk Dimmitt, MWD

Subject: Feasibility of Using "Reduced-Runoff" Surface Irrigation for Hay Crops Grown on Heavy Clay Soils in the Imperial Valley

INTRODUCTION

As you requested, I have investigated the feasibility of using the "Reduced-Runoff" (R-R) surface irrigation method to forage (alfalfa and sudangrass) hay crop production on "heavy" clay soils in the Imperial Valley. To that end, I reviewed all of my previous research related to irrigation-drainage and soil salinity processes in cracking clay soils, as well as reviewing the related sections in the March 2002 Assessment of Imperial Irrigation District's Water Use by the Natural Resources Consulting Engineers (NRCE Report). In order to find similarities and differences between fields in the Imperial Valley and those on which I conducted the R-R studies, I reviewed existing soils, land slopes and groundwater data to compare to the geohydrologic conditions under which my field studies were conducted. Furthermore, to set a context for evaluation of the reduced-runoff irrigation method effects on hay yields and to determine if the results were consistent with hay production elsewhere in the southwest, I also reviewed historic hay production and estimated water use in to the Imperial Valley.

Summary of Key Findings:

1. The NRCE report contains an incomplete understanding of irrigation-drainage-soil salinity processes in cracking clay soils as it accesses only a partial review of the available research and literature. As understanding these processes is essential towards evaluation of leaching requirements and water use in such soils, a more complete field measurement based description of soil-water processes in cracking clay soils is therefore provided.
2. The R-R surface irrigation method has been applied successfully to border-check irrigation of alfalfa and sudangrass hay grown on heavy clay soil classifications that comprise about 41% of the Imperial Valley soils.
3. Use of the R-R irrigation method resulted in minimal, if any, surface tail-water runoff and no adverse salinity effects on the field.
4. Accordingly, the R-R irrigation method is potentially applicable to all border-irrigated heavy cracking clay soils within Imperial Irrigation District (IID) which comprise 62 to 69% of the Imperial Valley soils. Moreover, the method can be readily applied to border-check irrigation of crops grown on mildly sloping fields that are found across more than half of the IID area.
5. Recent alfalfa hay production acreage in Imperial Valley has remained at, or near the average acreage during the 1988-2001 period. This suggests that Valley water use

associated with alfalfa hay production has remained relatively consistent during the past decade. In contrast, sudangrass hay production acreage in Imperial Valley has steadily decreased since peaking in 1997. This suggests that Valley water use associated with sudangrass hay production has been declining since 1997.

6. Estimated combined alfalfa and sudangrass hay production water use (product of harvested acreage and estimated water use, or ET_c) in the Imperial Valley has remained nearly constant, averaging just over 40% since 1996, but less than the 1988-2001 period average of nearly 42% of total Colorado River diversions. As with Finding #5 above, this suggests that water use associated with alfalfa and sudangrass hay production in the Imperial Valley, while a major component of overall IID diversions, has remained a more-or-less constant fraction of such diversions notwithstanding fluctuations in yields.
7. Perhaps most importantly, use of the R-R irrigation method for alfalfa and sudangrass hay production on the heavy clay soils resulted in yield to applied water (Y/AW) ratios that were consistent with those expected from water-use-efficiency studies and those obtained in other California counties.

Following my discussion of the above findings is a listing of my peer-reviewed journal references used in support of my research related to these points. Also attached at the end of this memorandum is my current curriculum vitae containing all of my research publications to date.

DISCUSSION

Field Studies on Cracking Clay Soils

Cracking clay or heavy clay soils are commonly found in irrigated regions developed on old lake deposits such as those found in the Imperial and southern San Joaquin Valleys (e.g. Tulare Lake basin). These mixed alluvial, relatively high clay content soils accumulate at the lower elevations of the basin such that they are often accompanied by shallow water tables or groundwater systems. In semi-arid and arid regions, the shallow groundwater is usually saline due to a net upward flow, or evapotranspirative loss from the soil that leaves salts contained in the irrigation water behind. Heavy cracking clay soils pose special considerations in managing irrigated crop production related to infiltration, soil salinity and drainage. During the past two decades, extensive field studies on Imperial Valley soils have been conducted at the University of California Desert Research & Extension Center (UCDREC, formerly "Meloland Field Station") considering irrigation-drainage and soil salinity processes during forage crop production. These studies have taken place on a range of "heavy" clay soils subject to regular cracking during the growing season. Generally, these studies have found that the very slow rates of infiltration/drainage, potential soil salinity accumulation and crop production can all be managed while meeting the crop water requirements and achieving hay yields that are greater than average yields within the county. Forage crop production on cracking clay soils is of particular interest to the Imperial Valley since these soils comprise 62 to 69% of the Imperial Valley soils and alfalfa and sudangrass hay evapotranspiration demands alone account for more than 40% of the water diverted from the Colorado River into IID.